BOILER TUBE ANALYSIS

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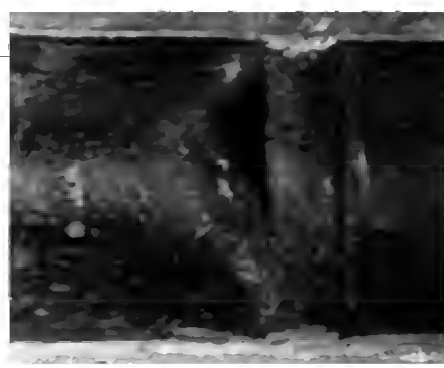
Finding the Root Cause is Critical

Identifying and correcting the root cause is essential. Shown on the following page are some of the failure mechanisms found in boiler tubes. When you see tubes in your boiler like those illustrated, determine and eliminate the root cause of the problem.

1.Caustic Attack .

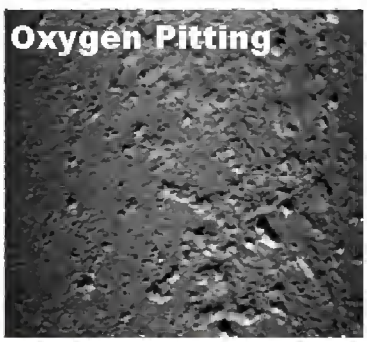
Symptoms: **Localized wall loss on the inside diameter (ID) surface of thetube, resulting in increased stress and strain in the tube wall.**
Causes: **Caustic attack occurs when there is excessive deposition on ID tube surfaces. This leads to diminished cooling water flow in contact with the tube, which in turn causes local under-deposit boiling and concentration of boiler water chemicals. If combined with boiler water chemistry upsets of high pH, it results in a caustic condition which *corrosively attacks and breaks down protective magnetite***



CAUSTIC ATTAC

2.Oxygen Pitting .

Symptoms: **Aggressive localized corrosion and loss of tube wall, . Flooded or non-drainable surfaces are most susceptible during outage periods.** **Causes:** **Oxygen pitting occurs with the presence of excessive oxygen in boiler water. It can occur during operation as a result of in-leakage of air at pumps, or failure in operation of pre-boiler water treatment equipment. This also may occur during extended out-of-service periods, such as outages and storage, if proper procedures are not followed in lay-up. Non-drainable locations of boiler circuits, such as superheater loops, sagging horizontal superheater and reheater tubes, and supply lines, are especially susceptible. More generalized oxidation of tubes during idle periods is sometimes referred to as** ***out-of-service corrosion.*** **Wetted surfaces are subject to oxidation as the water reacts with the iron to form iron oxide. When corrosive ash is present, moisture on tube surfaces from condensation or water washing can react with elements in the ash to form acids that lead to a much more aggressive attack on metal surfaces.**



3.Hydrogen Damage.

Symptoms: **Intergranular micro-cracking. Loss of ductility or embrittlement of the tube material leading to brittle catastrophic rupture.**

Causes: **Hydrogen damage is most commonly associated with excessive deposition on ID tube surfaces, coupled with a boiler water low pH excursion. Water chemistry is upset, such as what can occur from condenser leaks, particularly with salt water cooling**

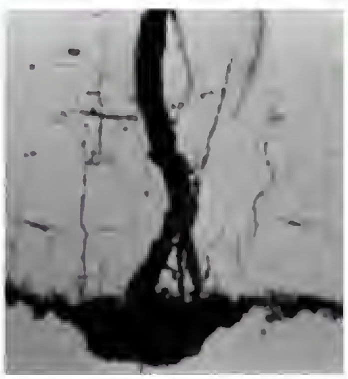
medium, and leads to acidic (low pH) contaminants that can be concentrated in the deposit. Under-deposit corrosion releases atomic hydrogen which migrates into the tube wall metal, reacts with carbon in the steel (decarburization) and causes intergranular separation.

4.Acid Attack.

Symptoms: **Corrosive attack of the internal tube metal surfaces, resulting in an irregular pitted or,in extreme cases, a “swiss cheese” appearance of the tube ID.**
Causes: **Acid attack most commonly is associated with poor control of process during boiler chemical cleanings and/or inadequate post-cleaning passivation of residual acid.**

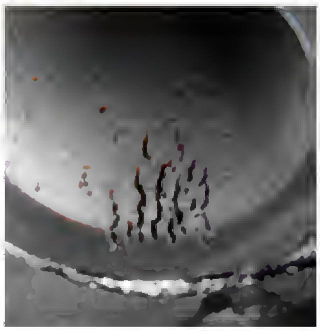
5.Stress Corrosion Cracking (SCC)

Symptoms: **Failures from SCC are characterized by a thick wall,brittle-type crack. May be found at locations of higher external stresses,such as near attachments.**



Causes: **SCC most commonly is associated with austenitic (stainless steel) superheater materials and can lead to either transgranular or intergranular crack propagation in the tube wall. It occurs where a combination of high-tensile stresses and a corrosive fluid are present. The damage results from cracks that propagate from the ID. The source of corrosive fluid may be carryover into the superheater from the steam drum or from contamination during boiler acid cleaning ,if the superheater is not properly protected.**

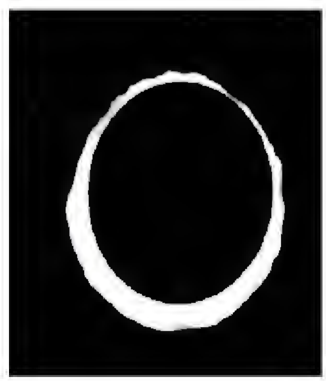
6.Waterside Corrosion Fatigue



Symptoms: **ID initiated, wide transgranular cracks which typically occur adjacent to external attachments.**

Causes: **Tube damage occurs due to the combination of thermal fatigue and corrosion. Corrosion fatigue is influenced by boiler design, water chemistry,boiler water oxygen content and boiler operation. A combination of these effects leads to the breakdown of the protective magnetite on the ID surface of the boiler tube. The loss of this protective scale exposes tube tocorrosion.The locations of attachments and external weldments, such as buckstay attachments, seal plates and scallop bars, are most susceptible. The problem is most likely to progress during boiler start-up cycles.**

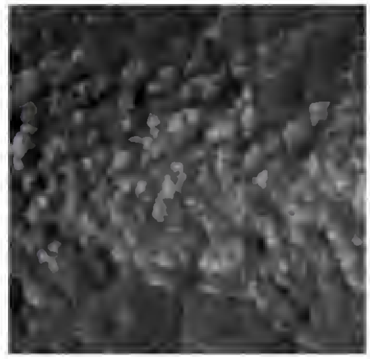
7.Superheater Fireside Ash Corrosion



Symptoms: **External tube wall loss and increasing tube strain. Tubes commonly have a pock-marked appearance when scale and corrosion products are removed.**

Causes: **Fireside ash corrosion is a function of the ash characteristics of the fuel and boiler design. It usually is associated with coal firing, but also can occur for certain types of oil firing. Ash characteristics are considered in the boiler design when establishing the size, geometry and materials used in the boiler. Combustion gas and metal temperatures in the convection passes are important considerations. Damage occurs when certain coal ash constituents remain in a molten state on the superheater tube surfaces.This molten ash can be highly corrosive.**

8.High-temperature Oxidation



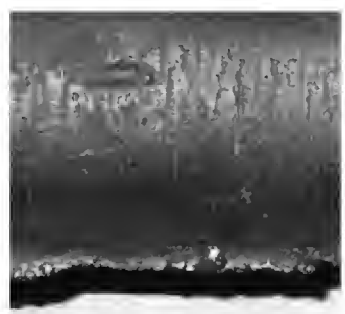
Similar in appearance and often confused with fireside ash corrosion,high-temperature oxidation can occur locally in areas that have the highest outside surface temperature relative to the oxidation limit of the tube material.Determining the actual root cause between the mechanisms of ash corrosion or high-temperature oxidation is best done by tube analysis and evaluation of both ID and OD scale and deposits.

9.Waterwall Fireside Corrosion

Symptoms: **External tube metal loss (wastage) leading to thinning and increasing tube strain.**

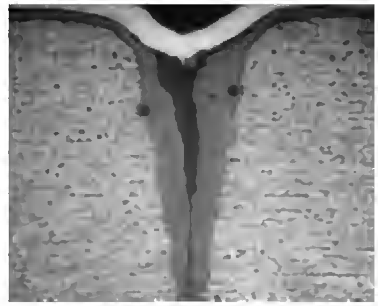
Causes: **Corrosion occurs on external surfaces of waterwall tubes when the combustion process produces a reducing atmosphere (substoichiometric).This is common in the lower furnace of process recovery boilers in the pulp and paper industry. For conventional fossil fuel boilers, corrosion in the burner zone usually is associated with coal firing. Boilers having maladjusted burners or operating with staged air zones to control combustion can be more susceptible to larger local regions possessing a reducing atmosphere, resulting in increased corrosion rates.**

10.Fireside Corrosion Fatigue



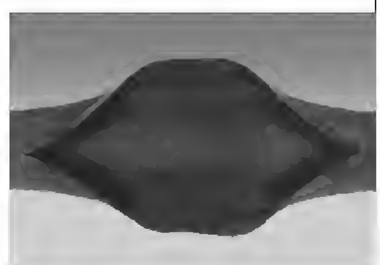
Symptoms: **Tubes develop a series of cracks that initiate on the outside diameter (OD) surface and propagate into the tube wall. Since the damage develops over longer periods, tube surfaces tend to develop appearances described as "elephant hide," "alligator hide" or craze cracking. Most commonly seen as a series of circumferential cracks. Usually found on furnace wall tubes of coal-fired once-through boiler designs, but also has occurred on tubes in drum-type boilers.**

Causes: **Damage initiation and propagation result from corrosion in combination with thermal fatigue. Tube OD surfaces experience thermal fatigue stress cycles which can occur from normal shedding of slag,sootblowing or from cyclic operation of the boiler. Thermal cycling, in addition to subjecting the material to cyclic stress, can initiate cracking of the less elastic external tube scales and expose the tube base material to repeated corrosion**



Short-term Overheat

Symptoms: **Failure results in a ductile rupture of the tube metal and is normally characterized by the classic "fish mouth" opening in the tube where the fracture surface is a thin edge.**



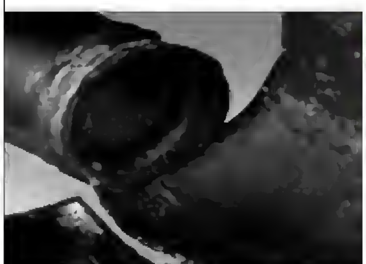
Causes: **Short-term overheat failures are most common during boiler start up. Failures result when the tube metal temperature is extremely elevated from a lack of cooling steam or water flow. A typical example is when superheater tubes have not cleared of condensation during boiler start-up,obstructing steam flow. Tube metal temperatures reach combustion gas temperatures of 1600°F or greater which lead to tube failure.**

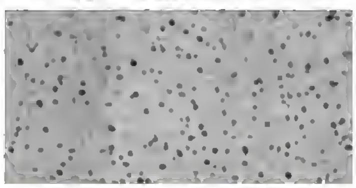
Long-term Overheat

Symptoms: **The failed tube has minimal swelling and a longitudinal split thatis narrow when compared to short-term overheat. Tube metal often has heavyexternal scale build-up and secondary cracking.**

Causes: **Long-term overheat occurs over a period of months or years. Superheater and reheat superheater tubes commonly fail after many years of service, as a result of creep. During normal operation, alloy superheater tubes will experience increasing temperature and strain over the life of the tube until the creep life is expended. Furnace water wall tubes also can fail from long-term overheat. In the case of water wall tubes, the tube temperature increases abnormally, most commonly from waterside problems such as deposits, scale or restricted flow. In the case of either superheater or water wall tubes, eventual failure is by creep rupture.**

11.Graphitization

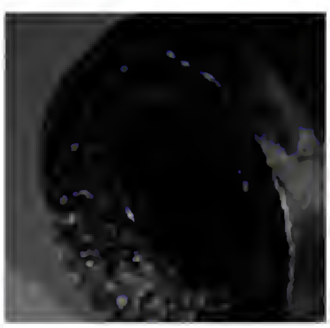




Symptoms: **Failure is brittle with a thick edge fracture.**

Causes: **Long-term operation at relatively high metal temperatures can result in damage in carbon steels of higher carbon content, or carbon-molybdenum steel, and result in a unique degradation of the material in a manner referred to as graphitization. These materials, if exposed to excessive temperature,will experience dissolution of the iron carbide in the steel and formation of graphite nodules, resulting in a loss of strength and eventual failure.**

12.Dissimilar Metal Weld (DMW) Failure



Symptoms: **Failure is preceded by little or no warning of tube degradation.Material fails at the ferritic side of the weld, along the weld fusion line. A failure tends to be catastrophic in that the entire tube will fail across the circumference of the tube section.**

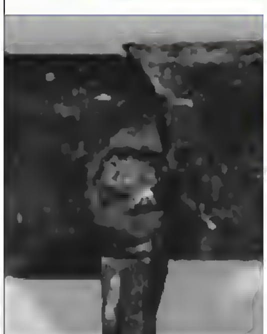
Causes: **DMW describes the butt weld where an autenitic (stainless steel) material joins a ferritic alloy, such as SA213T22, material. Failures at DMW locations occur on the ferritic side of the butt weld.**

These failures are attributed to several factors: high stresses at the austenitic to ferritic interface due to differences in expansion properties of the two materials, excessive external loading stresses and thermal cycling, and creep of the ferritic material. As a consequence, failures are a function of operating temperatures and unit design.

13.Erosion .

Symptoms: **Tube experiences metal loss from the OD of the tube. Damage will be oriented on the impact side of the tube. Ultimate failure results from rupture due to increasing strain as tube material erodes away.** ***Causes:*** **Erosion of tube surfaces occurs from impingement on the externalsurfaces. The erosion medium can be any abrasive in the combustion gas flow stream, but most commonly is associated with impingement of fly ash or soot blowing steam. In cases where soot blower steam is the primary cause, the erosion may be accompanied by thermal fatigue.**

14.Mechanical Fatigue.



Symptoms: **Damage most often results in an OD initiated crack. Tends to be localized to the area of high stress or constraint.**
Causes: **Fatigue is the result of cyclical stresses in the component. Distinct from thermal fatigue effects, mechanical fatigue damage is associated with externally applied stresses. Stresses may be associated with vibration due to flue gas flow or sootblowers (high-frequency low-amplitude stresses),or they may be associated with boiler cycling (low-frequency high-amplitude stress mechanism). Fatigue failure most often occurs at areas of constraint,such as tube penetrations, welds, attachments or supports.**

DETECTING TECHNIQUES

Detect, analyze and correct the problems leading to tube failures. B&W has developed a line of tube inspection services in evaluating boiler's tubing. These patented techniques have a proven track record of success in identify tubes that may lead to failures.

Nondestructive Oxide Thickness Inspection

An ultrasonic NDE test coupled to a computer model enables the calculation of remaining creep life for steam cooled superheater and reheater tubes.

Furnace wall Hydrogen damage Nondestructive Examination .

This ultrasonic test utilizes multiple transducers to scan tubes for attenuation due to hydrogen damage

Modular Automated Non-destructive Thickness Inspection.

The marriage of electronically acquired ultrasonic thickness measurements with computer-aided data management and analysis makes evaluation of wall thickness straightforward and efficient.

Fast-Scanning Thickness Gage

newest testing service uses technology developed the Electric Power Research Institute (EPRI).The FST-GAGE is an EMAT-based (ElectroMagnetic Acoustic Transducer), nondestructive examination technique that enables rapid scanning of boiler tubes to detect wall loss and internal tube damage.

SOURCE;The Babcock &Wilcox Company..

THANKS